The Future of Stellar Occultation For Atmosphere Research

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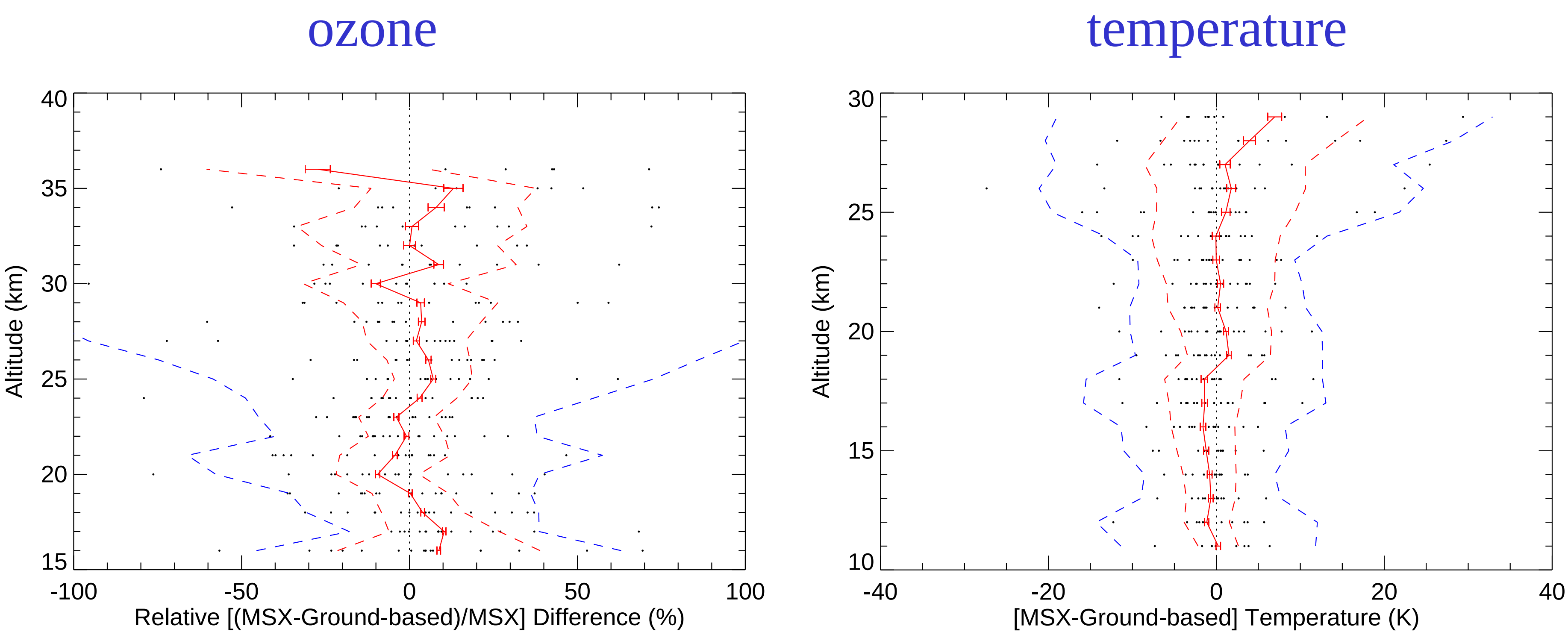
Stellar Occultation Technique

- Use stars as light source
- Advantages:
  - => daily global map
  - => high vertical resolution
  - => stellar refraction angles can be used to independently retrieve atmospheric bulk density, pressure and temperature information
    - => accurate tangent height registration
    - => accurate Rayleigh determination => more accurate composition retrievals
- Disadvantages:
  - => weaker source signals
    - => large-aperture instrument required to compensate signal to noise
    - => an imaging instrument required to discriminate against background atmospheric emissions
  - => multiple stellar sources => 2-axis gimballed system required for star acquisition
  - => refraction => a high-precision pointing instrument with ability to track and lock
  - => scintillation => an intrinsic noise source

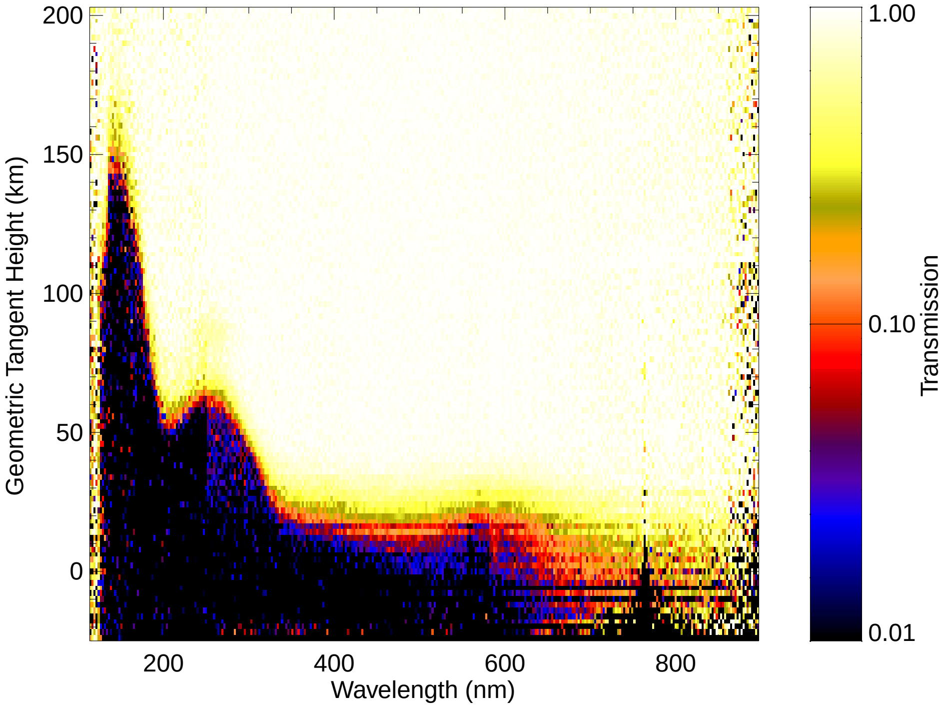
Only until recently that stellar occultation technique was successfully implemented for lower atmosphere applications (i.e. UVISI, GOMOS)

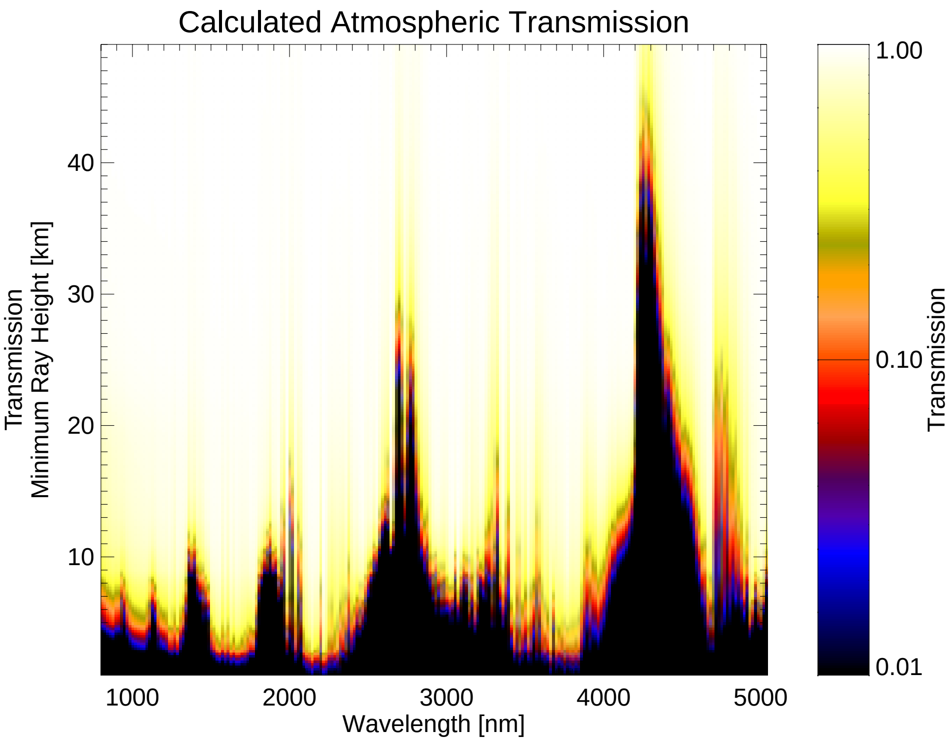
MSX/UVISI Stellar Occultations



While UVISI and GOMOS have successfully demonstrated that the stellar occultation is a viable technique to provide accurate ozone and atmospheric structure measurements, one can start investigating the design of an advanced instrument with enhanced capabilities.

Stellar Spectral Transmission





By conducting stellar occultation experiment in the short-IR, one can potentially obtain composition profiles of additional species such as O_2, CO_2, CO, CH_4, N_2O, etc., in addition to O_3, H_2O, NO_2 etc.

Discussion Topics

- Brief demonstration of an MSX/UVISI Stellar Occultation Experiment
- Issues affecting the feasibility of stellar occultation in the IR
  - Species optical depths

    => what species are likely to be retrieved?
  - Stellar refraction

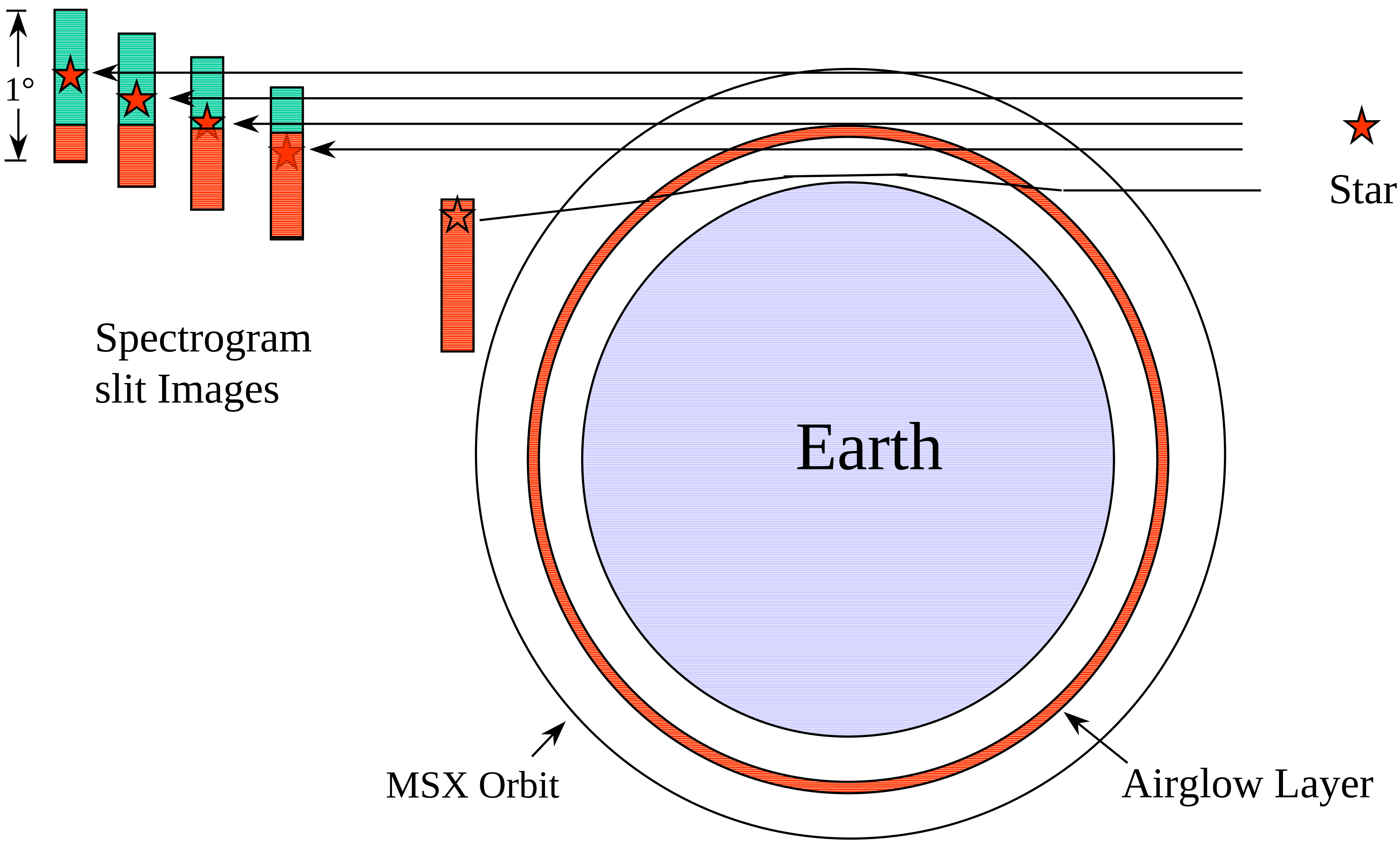
    => what are the effects of stellar refraction on atmospheric density/temperature measurements, the complexity of the retrieval algorithm, and instrument design considerations?
  - Stellar scintillation

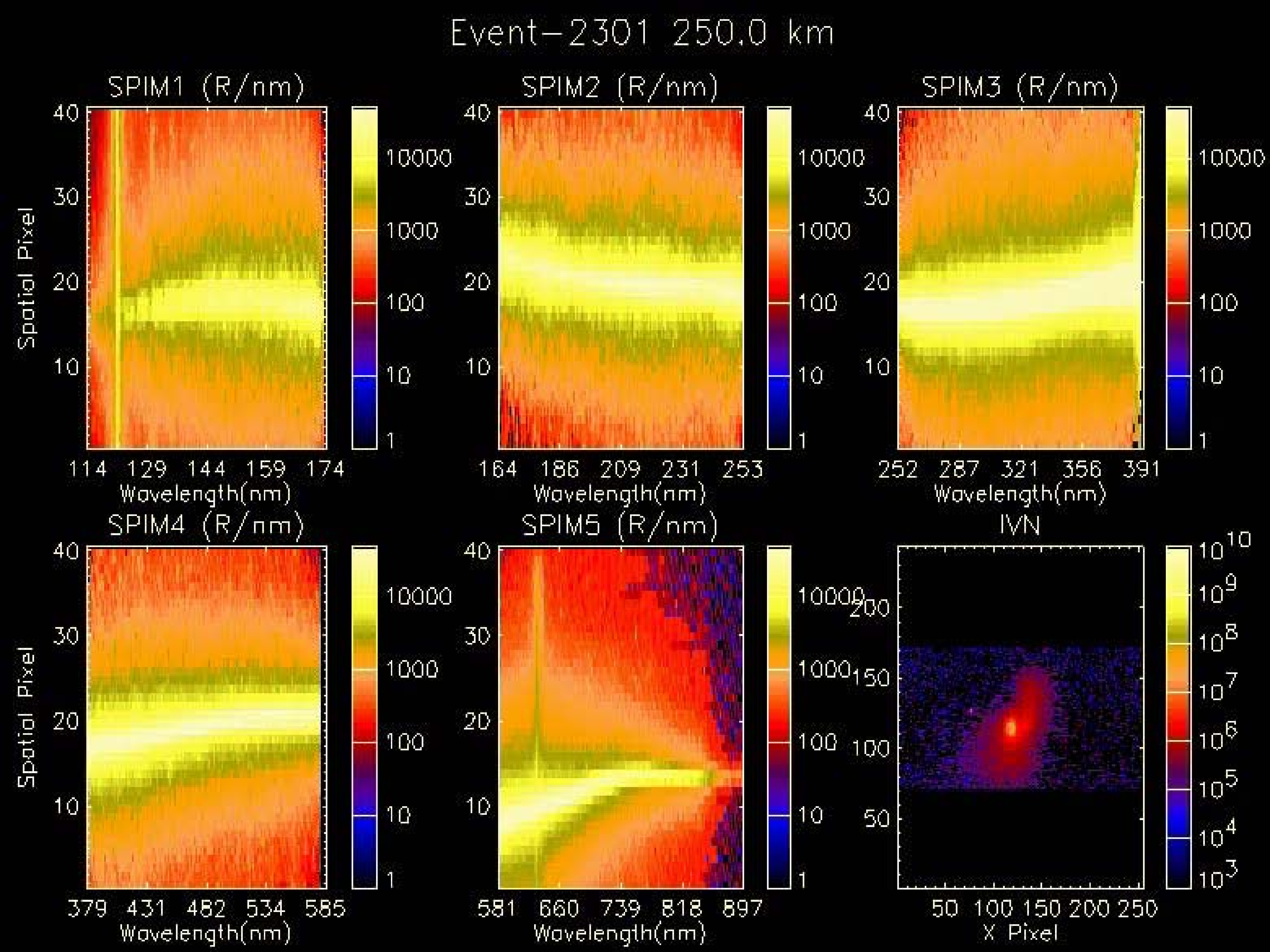
    => what are the effects of stellar scintillation on measurement noises and the complexity of the retrieval algorithm?
  - Atmospheric emissions

    => what are the effects of atmospheric emissions on measurements signal to noise and the instrument design considerations?
  - Number of available stars

    => how many occultations per day?

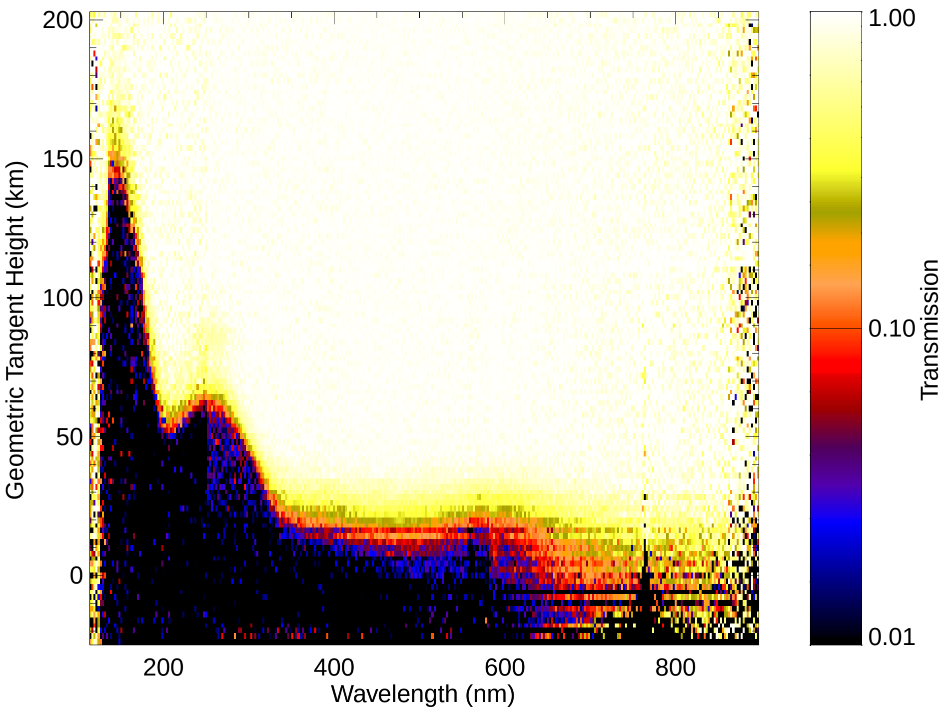
Stellar Occultation Observational Geometry



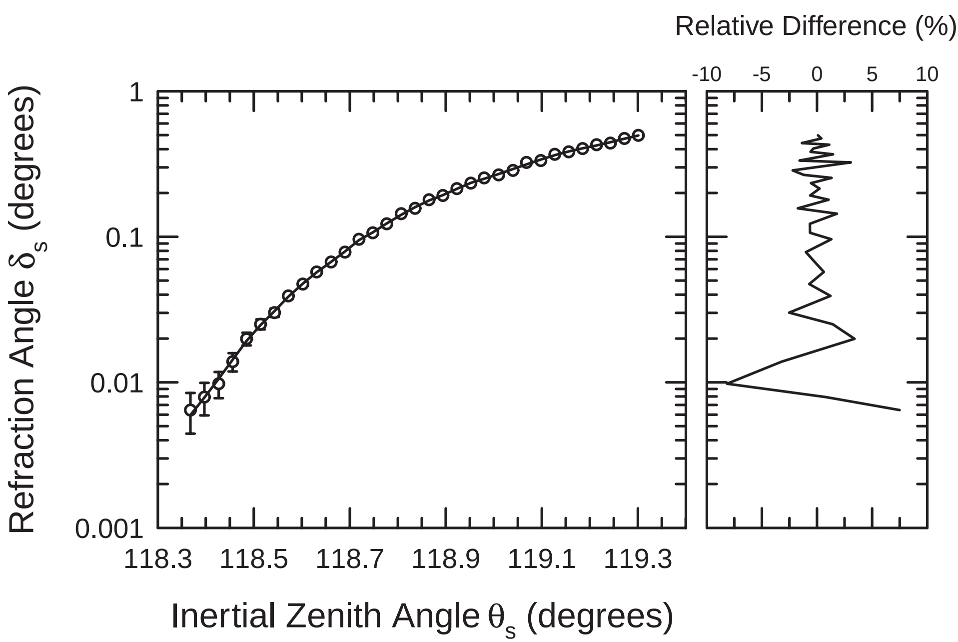

Event-2301 250.0 km
SPIM1 (R/nm)
SPIM2 (R/nm)
SPIM3 (R/nm)
SPIM4 (R/nm)
SPIM5 (R/nm)
IVN
Spatial Pixel
Wavelength(nm)
X Pixel
114 129 144 159 174
164 186 209 231 253
252 287 321 356 391
379 431 482 534 585
581 660 739 818 897
1 10 100 1000 10000
10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^{10}
10 20 30 40
50 100 150 200 250

Stellar Absorption and Refraction

Observed Transmission

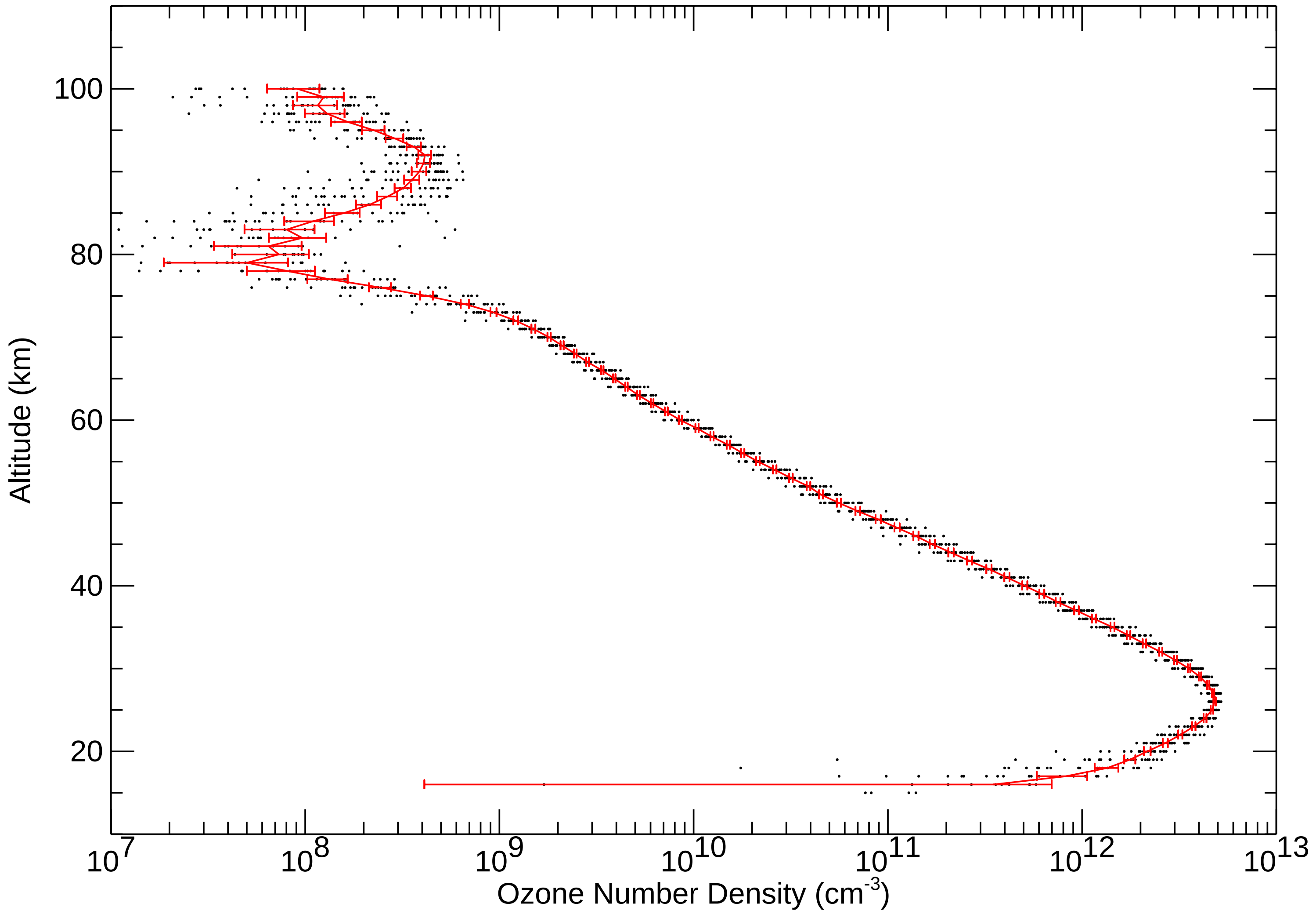


Observed Refraction Angle

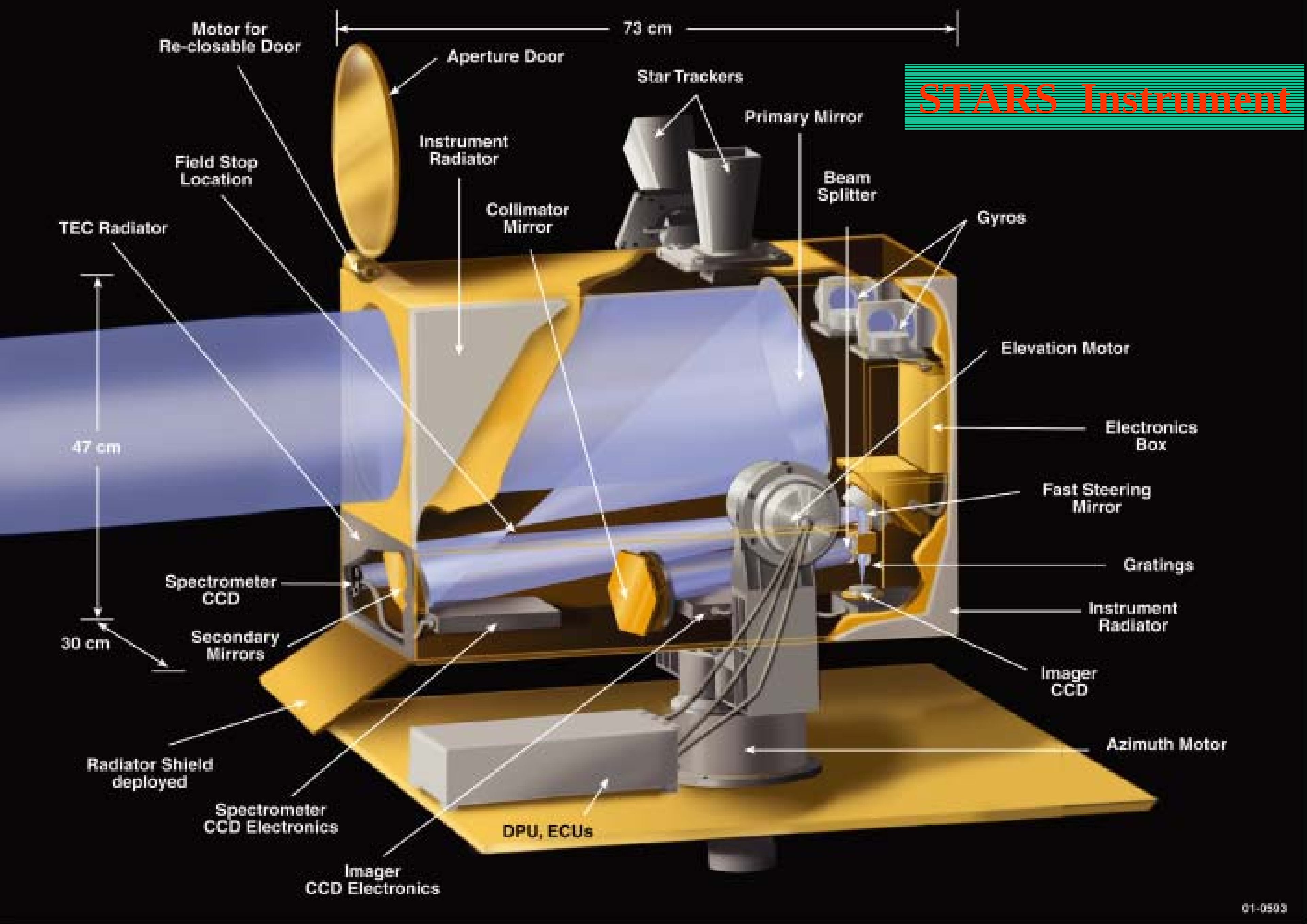


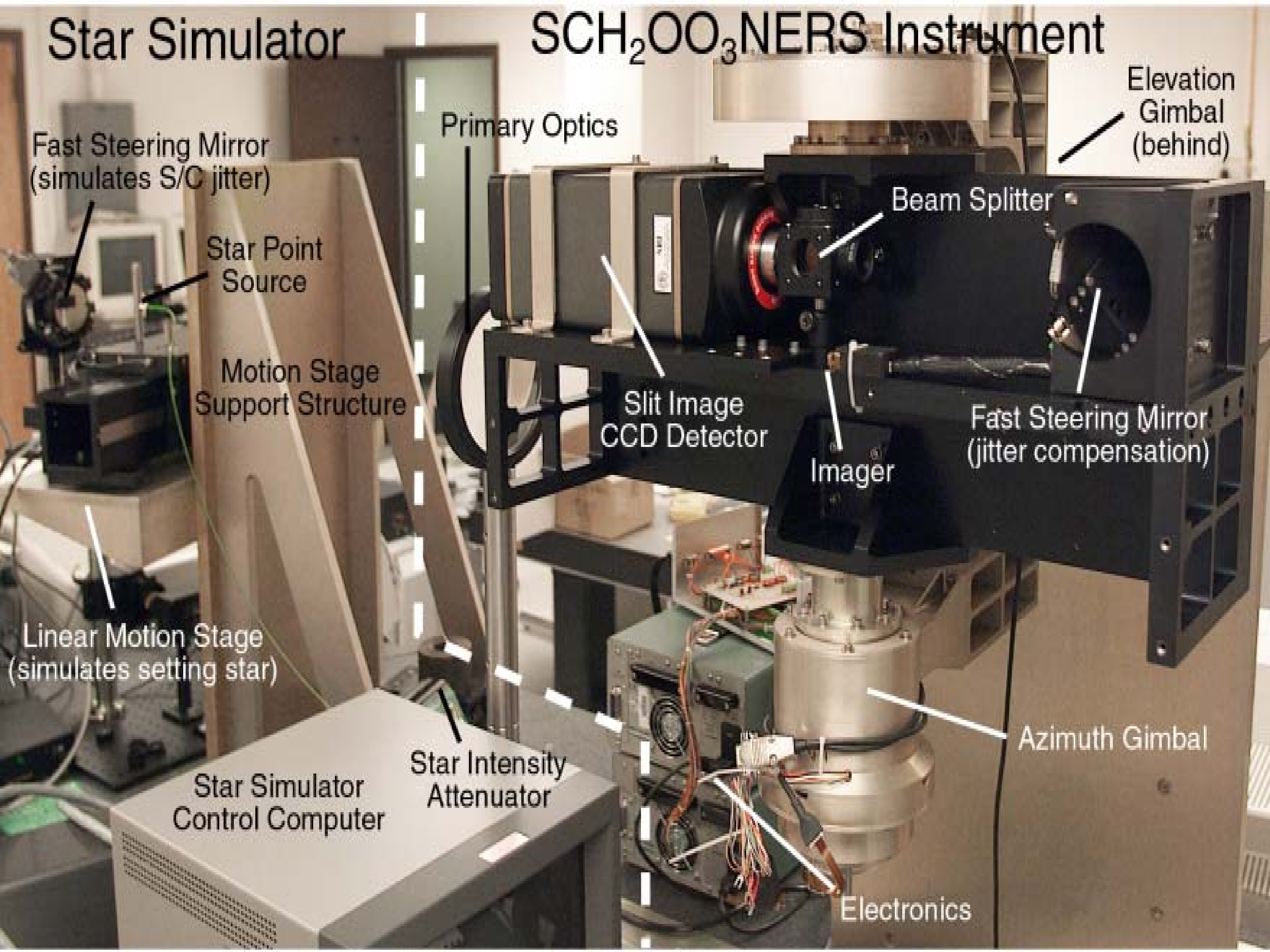
Examples of Retrieved O_3 Density Profiles

May 5-7, 1997 Lat: -17 (21 profiles)



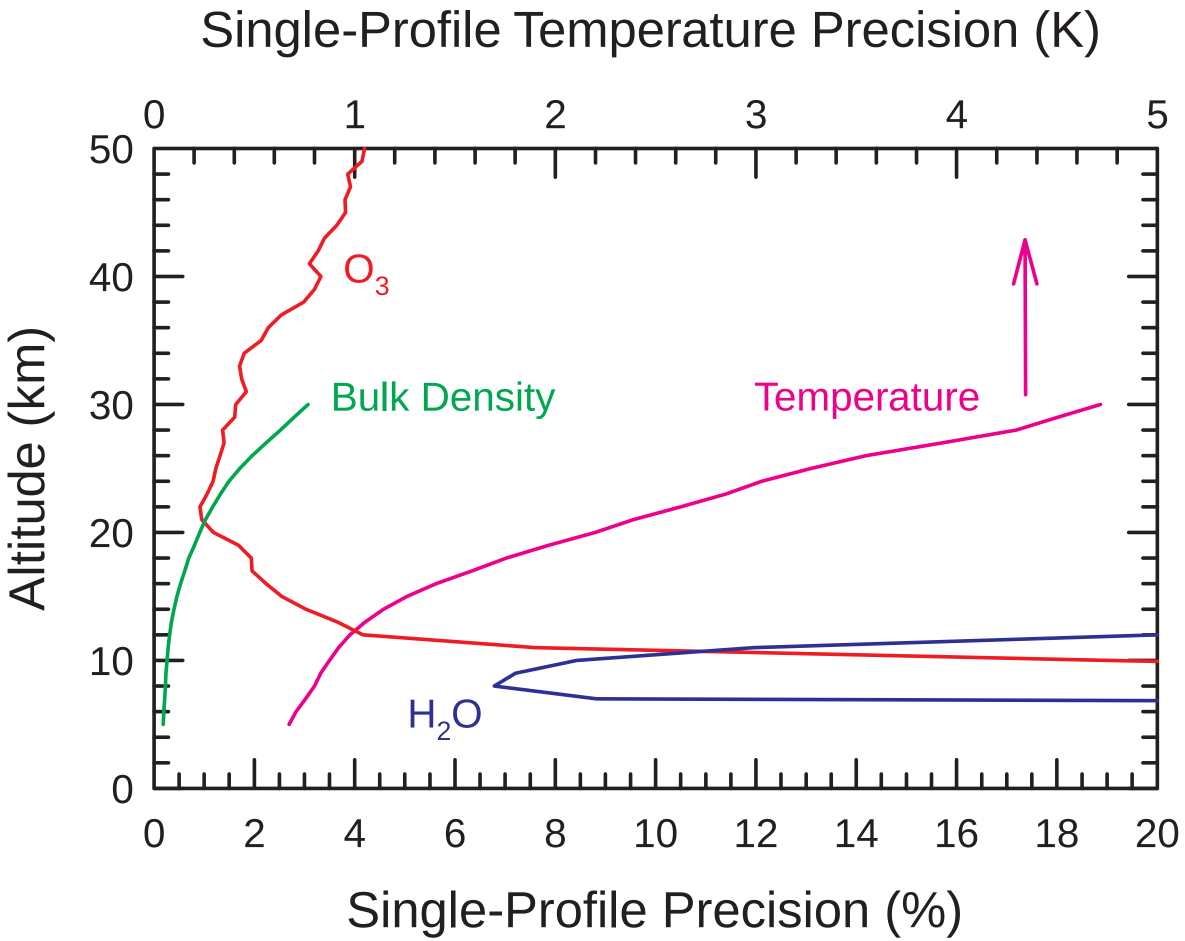
STARS Instrument





Star Simulator
SCH$_2$OO$_3$NERS Instrument
Elevation Gimbal (behind)
Primary Optics
Fast Steering Mirror (simulates S/C jitter)
Beam Splitter
Star Point Source
Motion Stage Support Structure
Slit Image CCD Detector
Fast Steering Mirror (jitter compensation)
Imager
Linear Motion Stage (simulates setting star)
Azimuth Gimbal
Star Intensity Attenuator
Star Simulator Control Computer
Electronics

STARS Predicted Measurement Capabilities

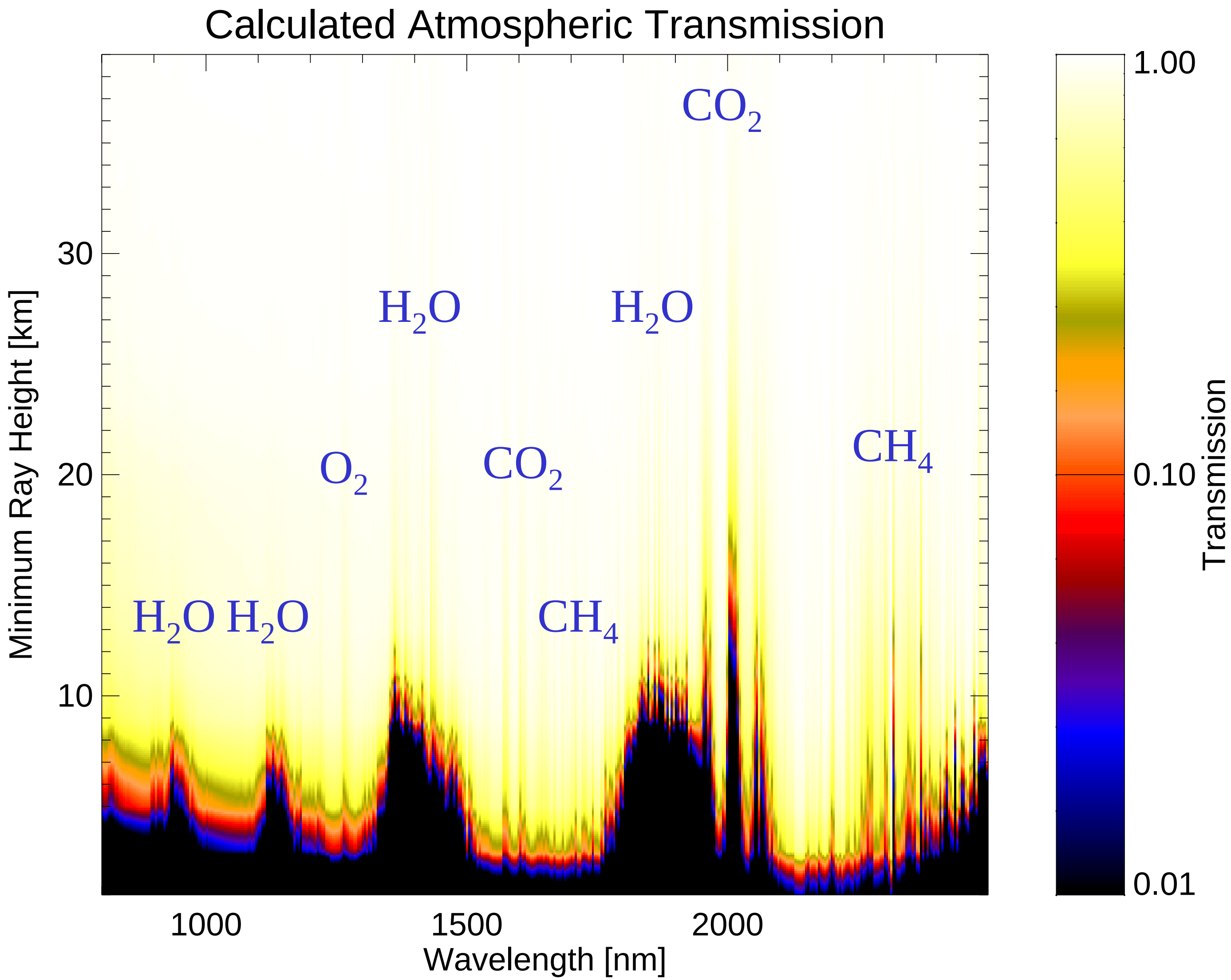


Single-profile precision expected for STARS data products as a function of altitude at 1-km resolution for a typical occultation using a visual magnitude 1.7 F3-type star.

The precision is roughly 2-3 times worse for a magnitude 3.3 star and varies slightly with the spectral type.

Scintillation introduced errors are not included

IR Stellar Occultation: Species Optical Depth



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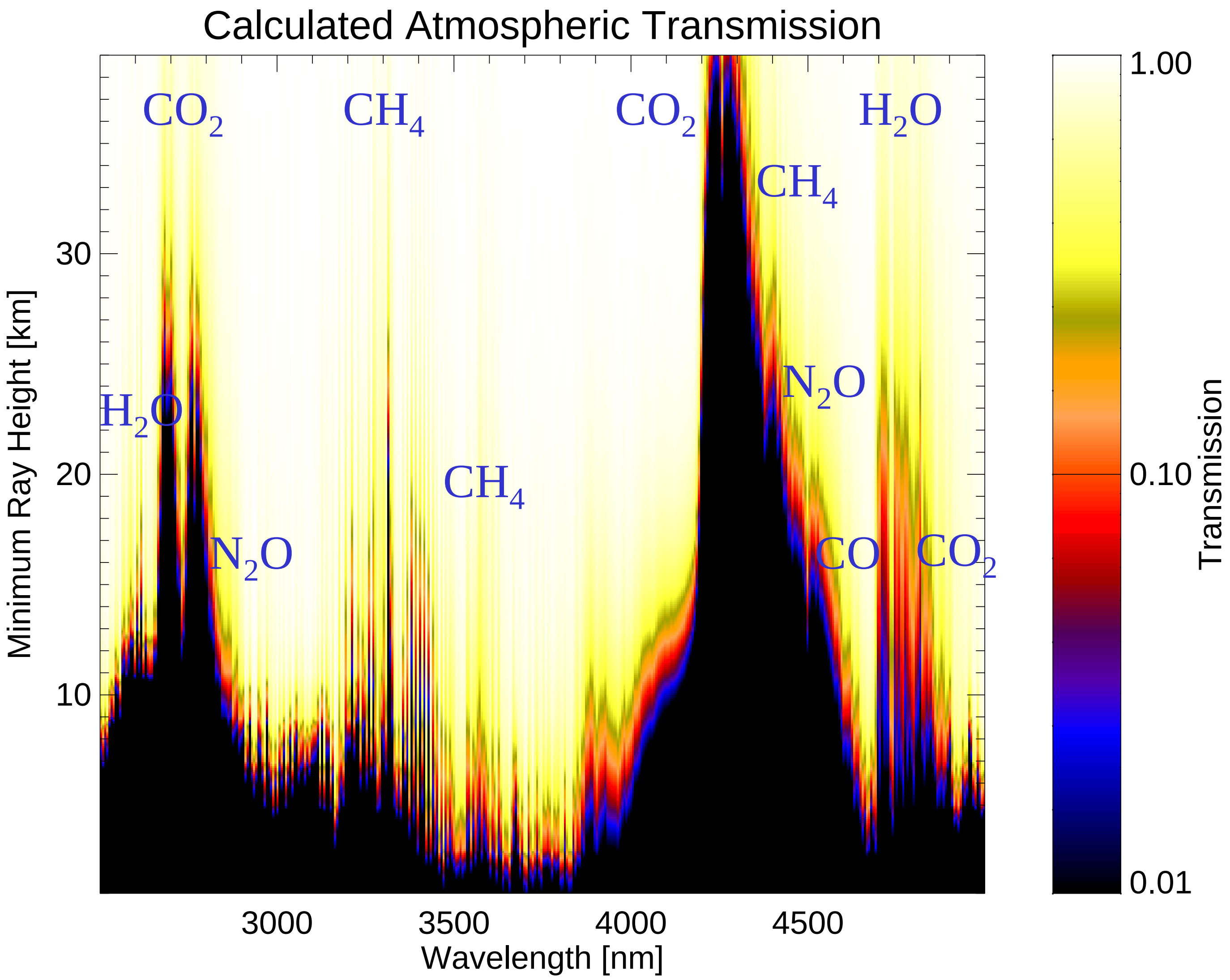
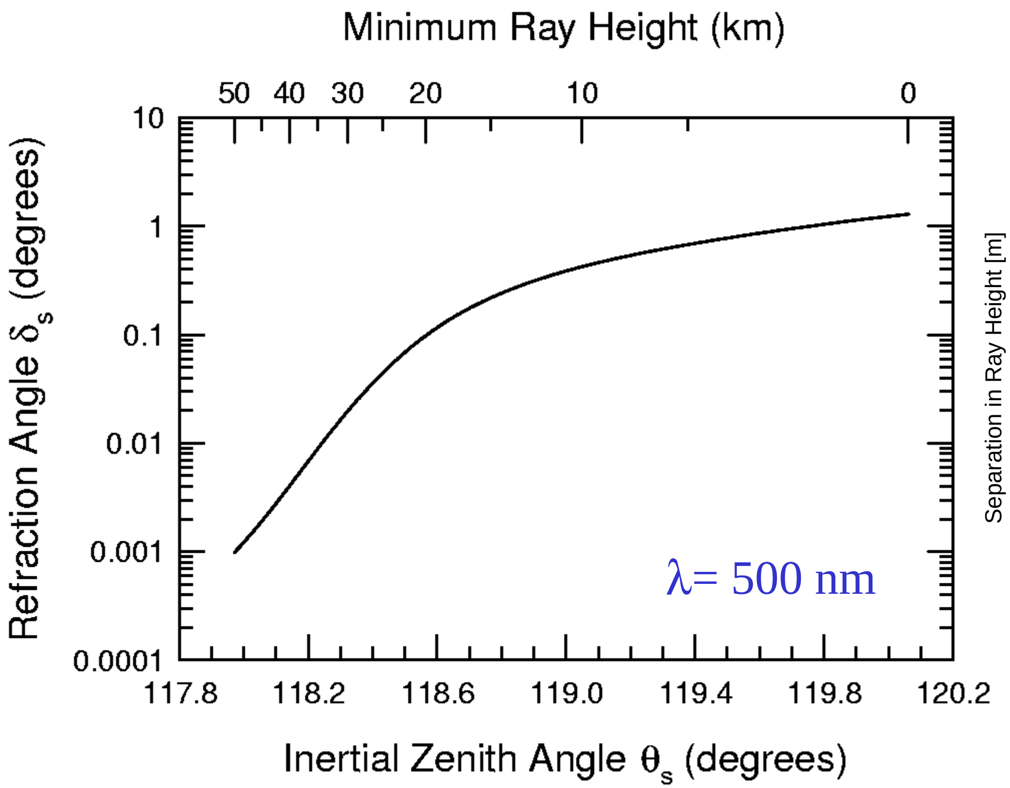
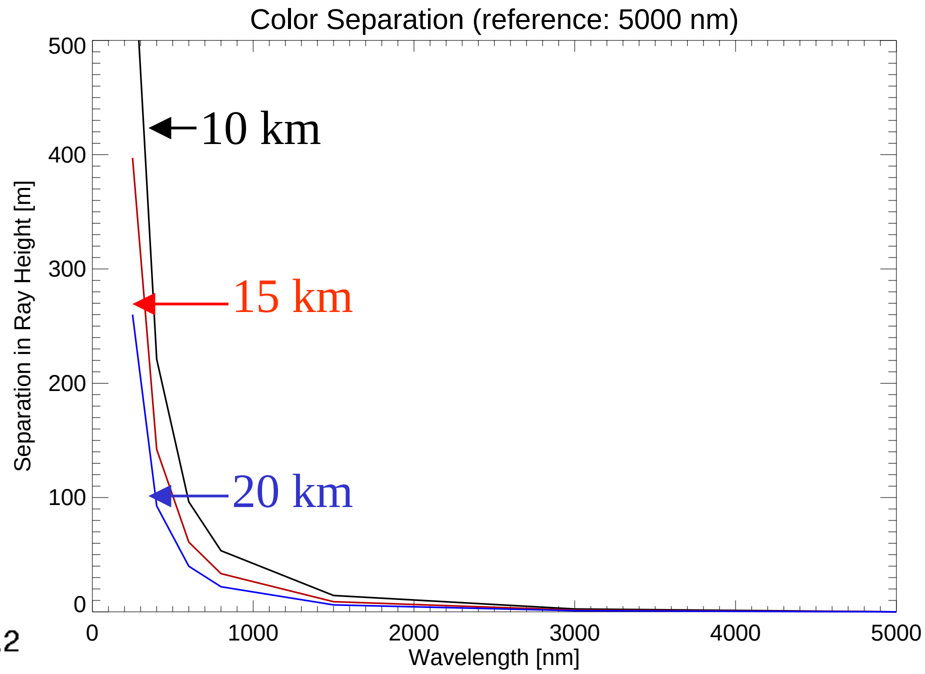


IR Stellar Occultation: Refraction Effects

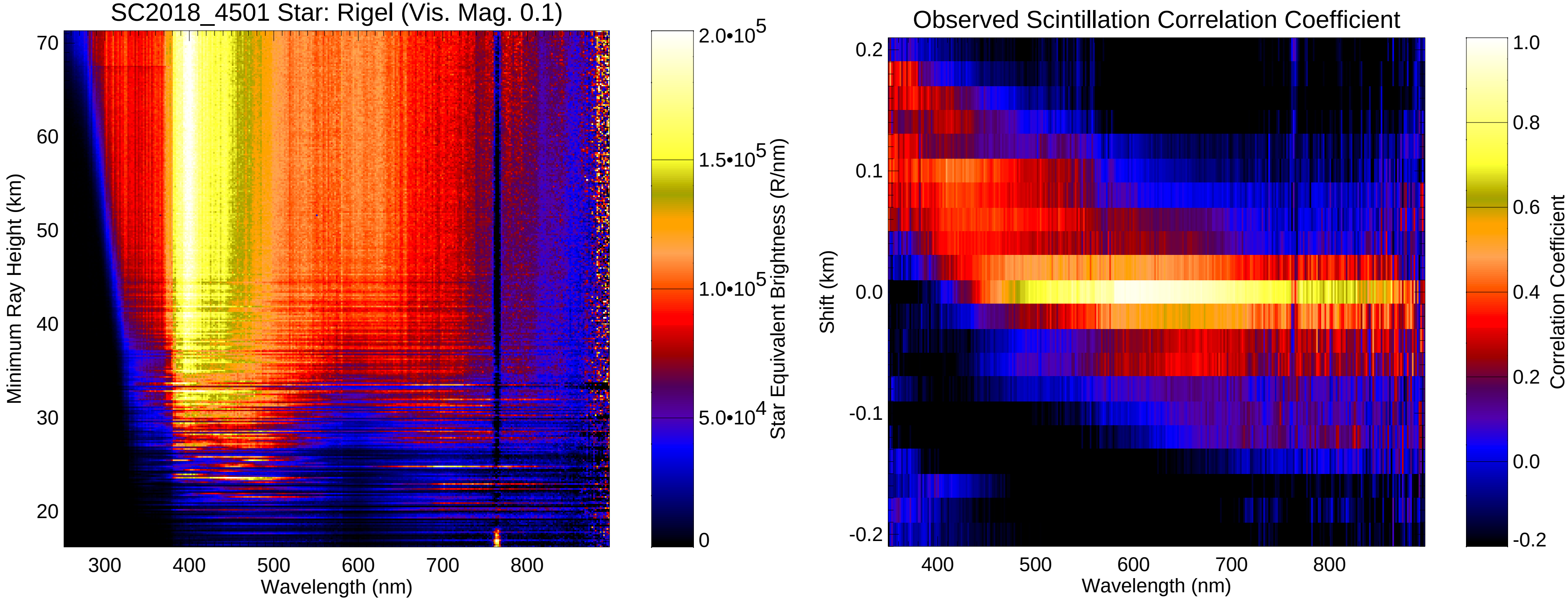




- Refraction angles vary from ~0.001° at 50 km tangent height to ~1.2° at surface.
  Refraction angle vs height relation varies slightly from 500 nm to 2500 nm, and does not vary at all from 2500 nm to 5000 nm.
- Minimum ray height differs for different colors and the amount of height separation varies with tangent height. At IR wavelengths, very small color separations are expected.

IR Stellar Occultation: Scintillation Effects

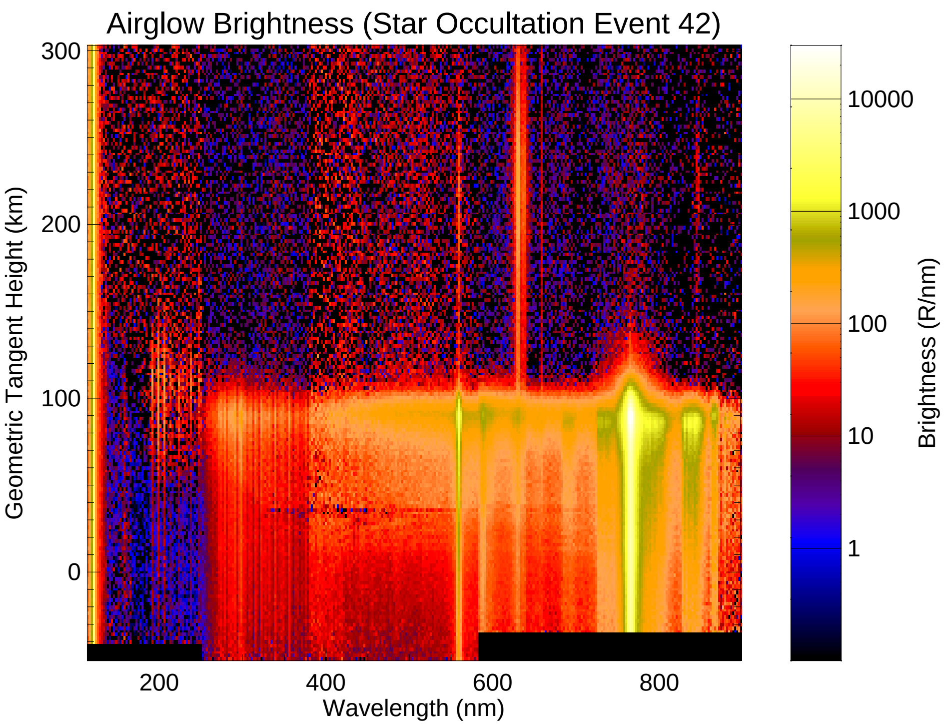
16.2 - 17.2 km



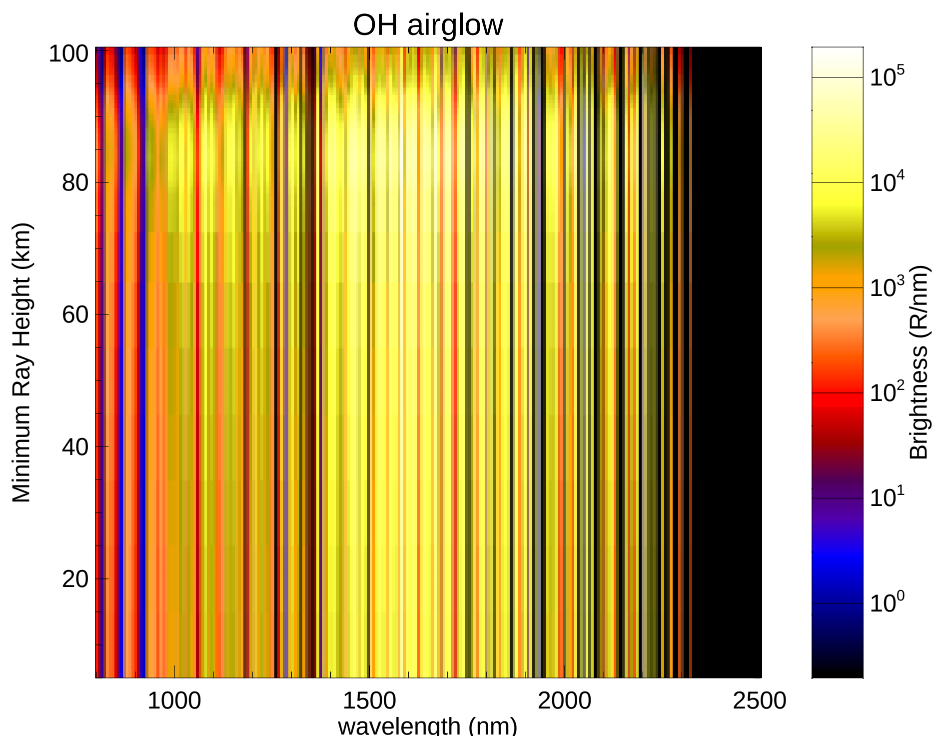
Stellar scintillation will be strongly spectral correlated in the IR, making the scintillation correction easier and composition retrievals more precise.

IR Stellar Occultation: Atmospheric Emissions

Observed by UVISI



Calculated

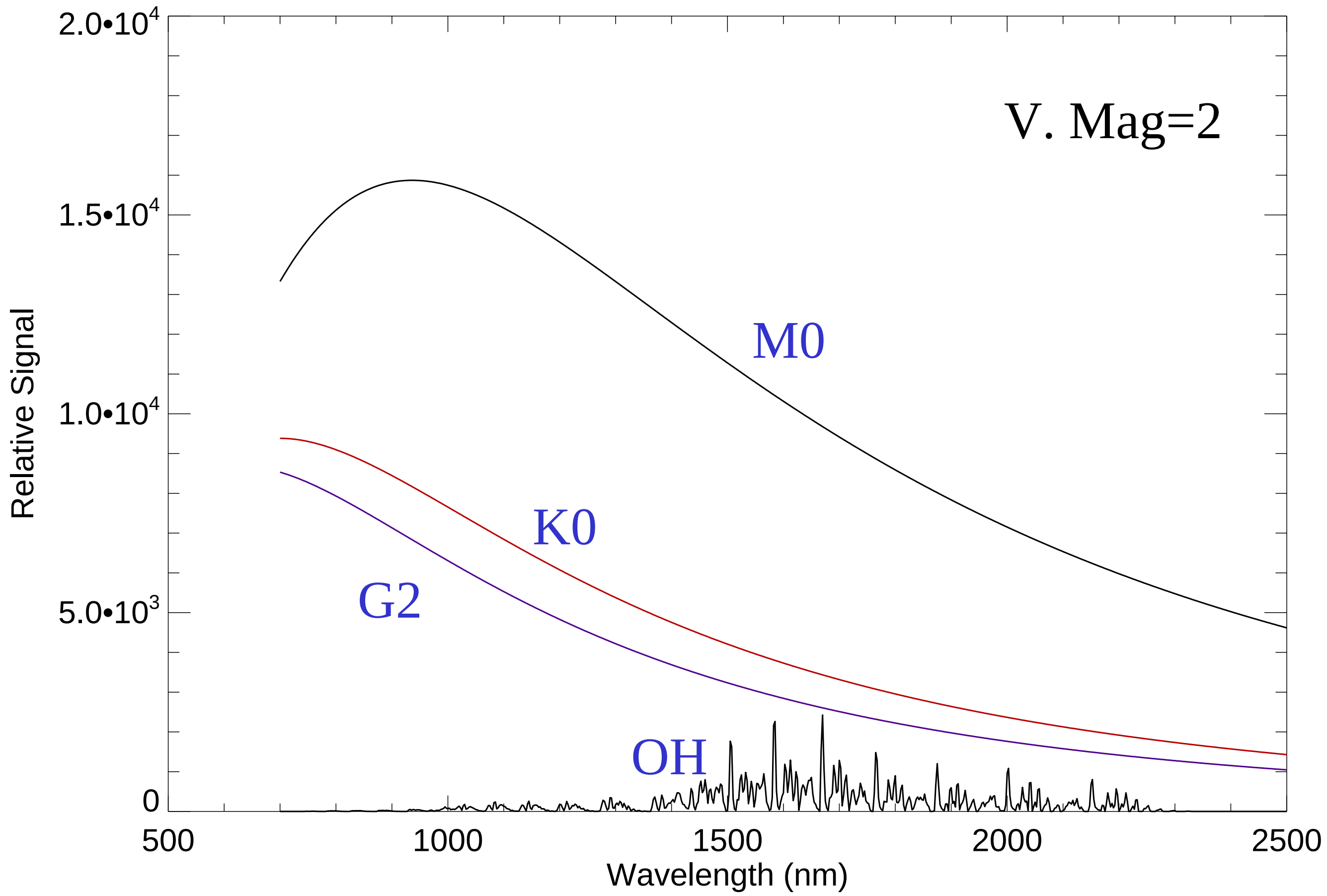


Brighter atmospheric emissions (i.e. OH nightglow) in the short IR are expected. An instrument which minimizes diffuse background emissions is required.

IR Stellar Occultation: Emission Discrimination

Star (point):
signals ∝ A

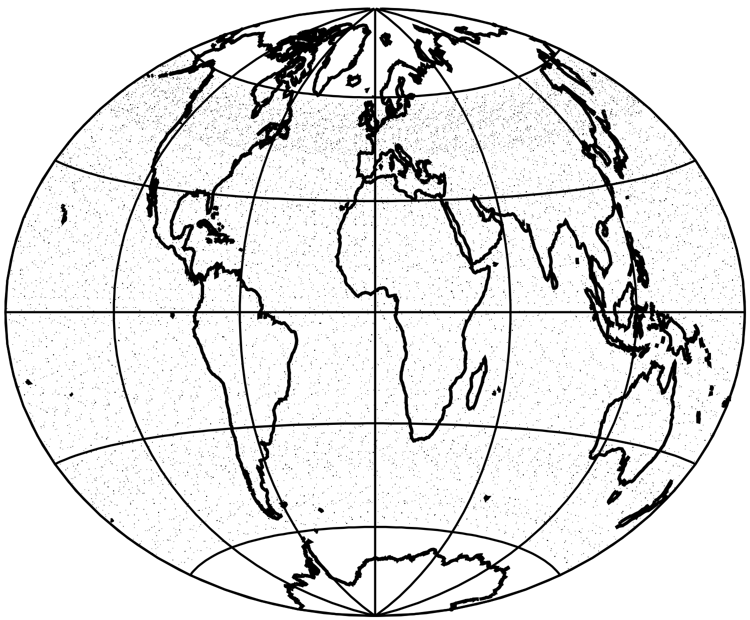
Airglow (diffuse):
signals ∝ AΩ



Instrument resolution: 5 nm
Instrument FOV: 0.01° x 0.075°
(as compared to UVISI: 0.1° x 1.0°)

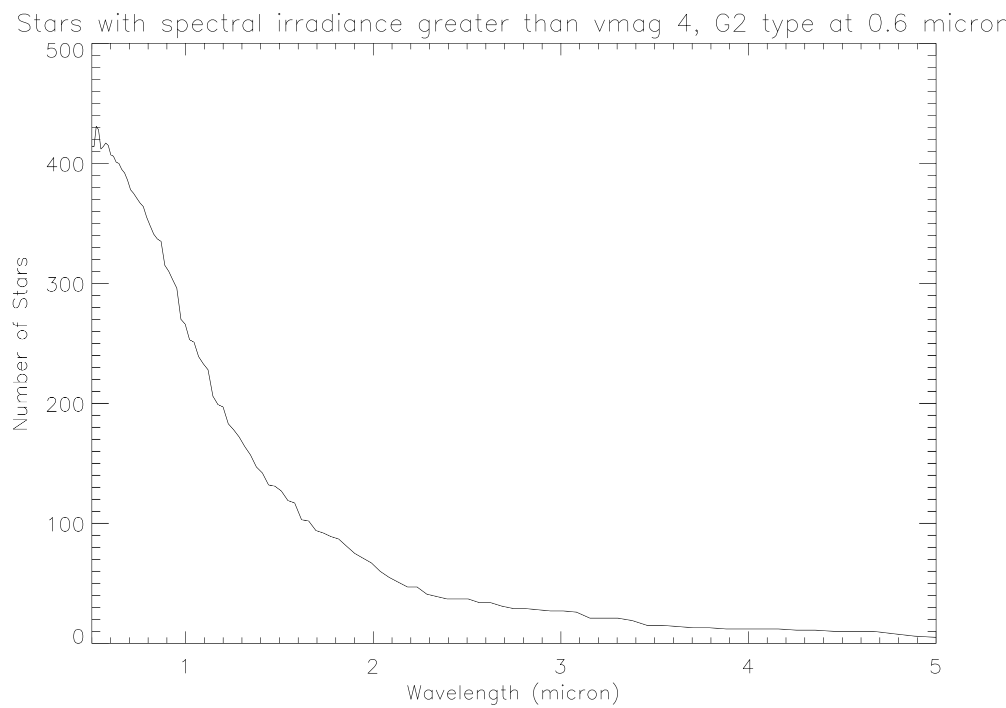
IR Stellar Occultation: Available Stars

STARS



1 month coverage, visible stars

(b)



Without detailed mission simulations, we estimate that more than 90 occultations per day can be conducted for extinction experiments shorter than 2.5 microns.

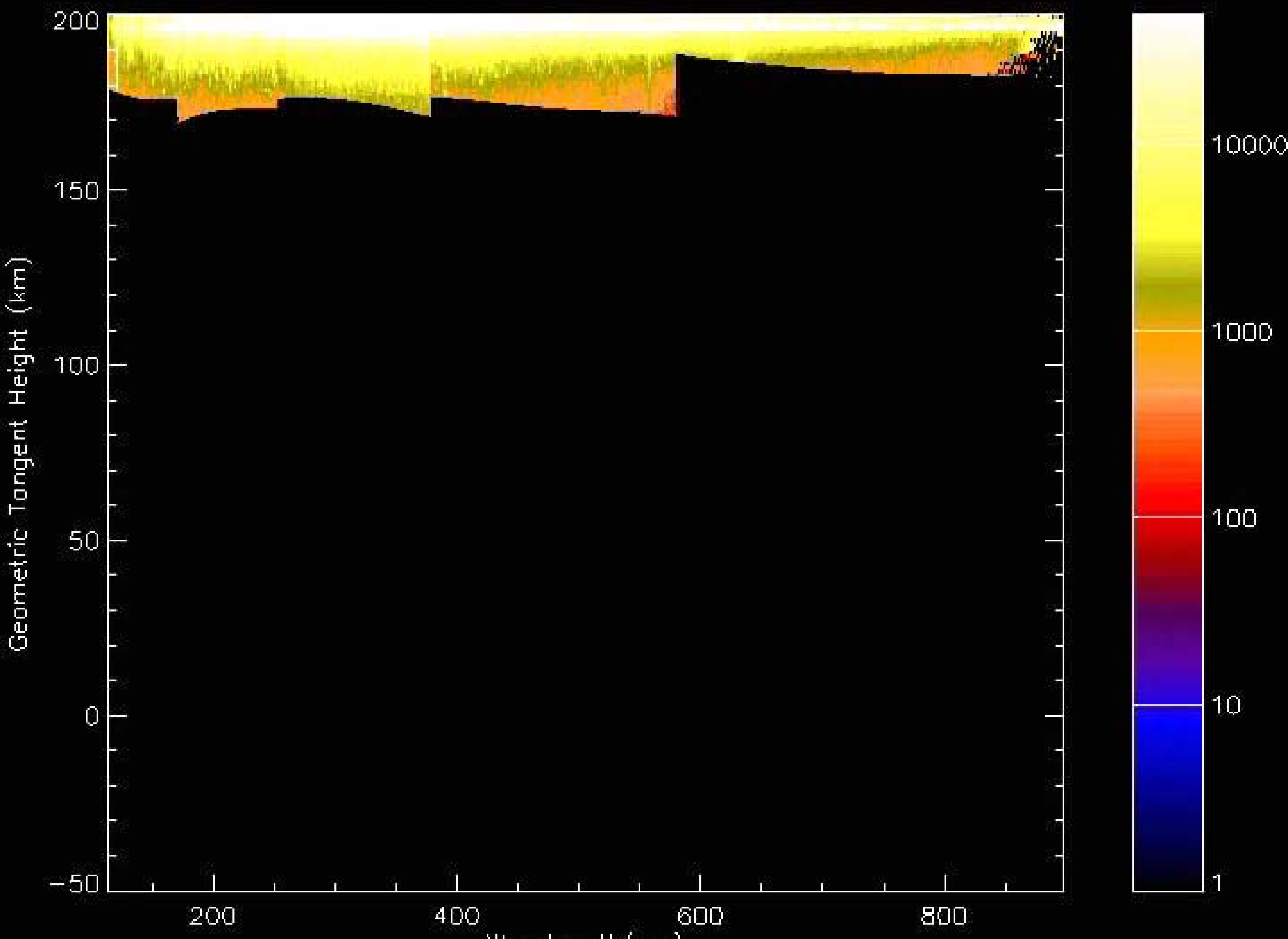
Summary

- Conducting stellar occultation in the IR can provide additional composition information about CO_2, CH_4, and N_2O, etc.
- The technique is feasible and the issues affecting its implementation and retrieval algorithms have been examined:
  - Atmospheric emissions

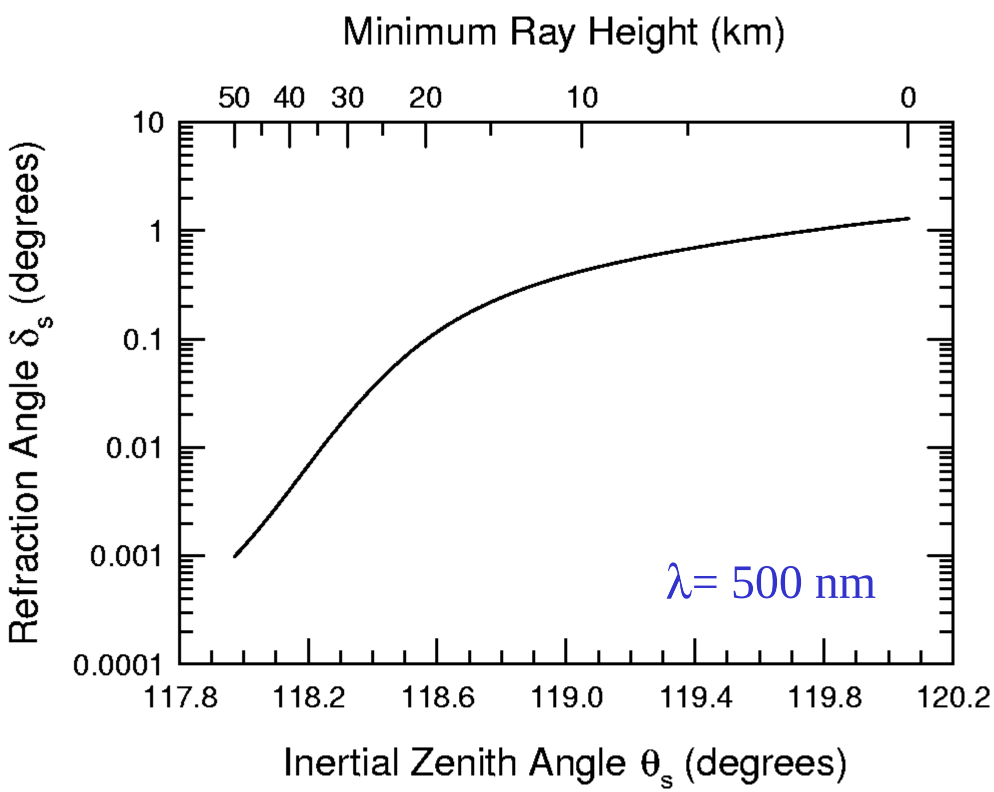
    => although bright, the small FOV instrument such as STARS, developed under the IIP program, effectively minimizes the diffuse airglow signals
  - Stellar refraction

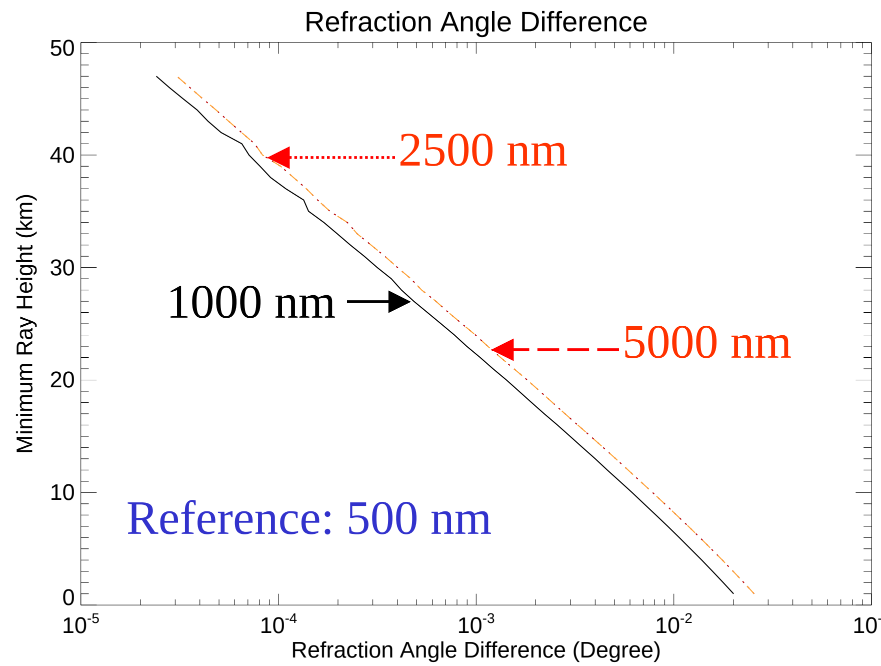
    => refraction angle measurements can still provide temperature/density/pressure information below 30 km
  - Stellar scintillation

    => stellar scintillation, one of the largest error sources for the retrievals, is no longer an important issue and can be easily treated in the retrievals
- More detailed spectrogragh and detector designs are underway


Geometric Tangent Height (km)
200
150
100
50
0
−50
200
400
600
800
10000
1000
100
10
1

IR Stellar Occultation: Refraction Effects





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